OREGON STATE UNIVERSITY

ATMOSPHERIC SCIENCE BRANCH
SCIENCE RESEARCH INSTITUTE
Corvallis, Oregon

Investigation of

INSTRUMENTATION AND TECHNIQUES FOR ARMY WEATHER OBSERVATION

Quarterly Progress Report No. 1

1 February 1962 through 30 April 1962

Signal Corps Contract Number DA-36-039 SC-89186
DA Project 3A99-27-005-07

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INVESTIGATION OF
INSTRUMENTATION AND TECHNIQUES
FOR
ARMY WEATHER OBSERVATION

Report No. 1

FIRST QUARTERLY PROGRESS REPORT
1 February 1962 through 30 April 1962

Signal Corps Contract Number DA-36-039 SC-89186
Continuation of Contract DA-36-039 SC-78918
DA Project No. 3A99-27-005-07

This study has as its object the creation of a body of knowledge concerning appropriate techniques on meso-meteorological scale applicable to Army operations as well as types and design criteria of meteorological instrumentation

Prepared by

Fred W. Decker
Kenneth H. Shreeve
James W. Sears

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PURPOSE

Data acquired and analysis conducted will aim at revealing the way in which characteristics of radar echoes change as functions of the topography, air movement, precipitation forms, and other factors. Prime radar data will consist of RHI scope studies, target reflectivity measurements, echo variability, and vertical growth studies. Other related measurements will include nuclei counts, standard weather observations, rawinsonde data obtained at nearby Salem U.S. Weather Bureau station, network precipitation studies, raindrop size distribution at selected points, and rate-of-precipitation records.

Task A. Analysis of previous data.

- Phase 1. Literature search.
- Phase 2. Review of 1959-61 data from Marys Peak and McCulloch Peak.
- Phase 3. Stipulation of operating doctrine for 1962-63 data acquisition.

Task B. Data Acquisition.

- Phase 1. Attach and calibrate auxiliary measurement equipment
- Phase 2. Operate AN/CPS-9 at McCulloch Peak.
- Phase 3. Obtain related data by direct operations.
- Phase 4. Gather related weather data by transcript of records.

Task C. Analysis of data.

- Phase 1. Construction of case studies.
- Phase 2. Preparation of summaries of factors common to case studies.
- Phase 3. Preparation of conclusions.

ABSTRACT

Resumption of operations with Weather Radar Set AN/CPS-9 at McCulloch Peak, Oregon, in February 1962 required a number of maintenance, repair, and adjustment steps to produce reliable weather radar data. In order to utilize the equipment to the greatest advantage while securing certain replacement parts, the staff explored experimentally the possibility of deriving more meaningful data from the weather radar echo video signal by recording on an R-scope photograph the echoes from individual pulses. Several operating periods also provided PPI photographs for ultimate comparison with TIROS photographs and for detailed analytical comparison with the precipitation data collected in a dense network of nearby observing points.

The results of the single-pulse preliminary study show such rapid fluctuations in the echo strength from a given volume of space that in the data examined the weather radar echo intensity from a given range had negligible correlation with the intensity of echo from the same range produced by the immediately preceding pulse. This indicated achievement of independence in only 0.005 sec or less, a time interval so brief as to warrant further examination under various weather conditions to determine whether meteorologically significant information may appear in such rapid fluctuations.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

On 25-27 February 1962 the project staff workers at OSU had opportunity to confer with Dr. Frank Ludlam of the University of London on his present hypothesis regarding hail formation and related subjects, including the use of radar for mesometeorological research. Dr. Ludlam appeared at OSU under auspices of the National Science Foundation and Oregon State University. He inspected the AN/CPS-9 installation and advised with staff researchers on advantageous use of the radar for revealing topographic effects.

On 3 May 1962 at the Oregon Academy of Science meeting at Lewis and Clark College at Portland, Oregon project personnel presented papers as follows:

"Biometeorology - an old science with a new look." --W.P. Lowry
"The graduate program in meteorology at Oregon State University."--Fred W. Decker
"Characterization of rainfall intensity by means of radar."--John F. Tatom
"Observations of ice condensation nuclei in various air mass conditions in western Oregon."--M.A. Fosberg
"The PREPI unit (precipitation profile indicator)." --K.H. Shreeve

On 27 April 1962 Mrs. Laura Smothers, Research Secretary in charge of ASB security procedures, attended the Orientation and Education Course in Industrial Security at Vancouver Barracks, Washington. Lectures, conferences, and films were presented to help in the control and handling of classified information at contractor facilities.

FACTUAL DATA

The record of radar photography during the past quarter appears in the catalog of PPI and RHI films following this page. Additional operations involved the perfection of photographic and scope techniques, radar maintenance, and radar adjustment, as follows:

Laboratory tests SPRAR (Single Pulse Radar Return) and adjustment of scope camera:	94 hours
AN/CPS-9 operations to secure SPRAR records:	15 3/4 hours
AN/CPS-9 operations for general storm records, including TIROS passages:	55 1/4 hours on 10 days
AN/CPS-9 operations for maintenance and adjustment:	21 1/2 hours
Operations conducted simultaneously with dense network of observers in nearby terrain:	on 6 days
Number of case studies made possible by data from simultaneous operations of field network and either SPRAR or RHI and PPI photography:	8

The study of echo variability requires some exploratory work prior to incorporation into any general operating doctrine for the year. Staff member Kenneth H. Shreeve and volunteer graduate student, John M. Steigner, cooperated in carrying out the program described as "SPRAR" on the pages following the film logs. This study comes under Task B, while the analysis conducted under Task C now provides feedback to assist in finalizing the operating doctrine for 1962 data under Task A.

When this contract took effect on 1 February 1962 the official negotiations had not concluded in the form needed to incur large expenses in this work. However, cooperating projects did provide some activity and insured an early start when the final documents arrived on 22 March 1962. Unfortunately, by that date the overcommitment of the available staff plus serious illness and hospitalization by one key member of the OSU group precluded the aggressive immediate start of a comprehensive literature search contemplated under Task A and the equally energetic program of data acquisition intended under Task B. However, the plan adopted did exploit a splendid opportunity made possible by the earlier acquisition of the Fairchild Oscillo-Record Camera by OSU, the grant by Tektronix of a Type 545A Oscilloscope with attachments, and the professional participation of John M. Steigner as an advanced graduate student working on his M.S. degree at OSU while on leave from the United States Air Force. The operations of the AN/CPS-9 during this quarter, therefore, took full advantage of personnel and facilities available on a cooperative basis without cost to the present contract. Beyond this, the dense network of observers for the precipitation studies received their support from the regional agricultural project W-73 in a cooperative arrangement with the OSU Department of Agricultural Engineering whereby all the operations came under direct control of the Atmospheric Science Branch. The continuation of this policy of cooperative operations should provide data for the present project which the budget would not otherwise support, and a considerable increase in efficiency should result.

S P R A R
(Single Pulse Radar Returns)

INTRODUCTORY CONSIDERATIONS:

Do radar pulse-to-pulse variations in a weather radar echo contain significant information? Several investigators (ref. 1,2,3) have suggested that these variations depend upon turbulence, wind sheer, and gustiness, among others. A review of the literature reveals little published data on this subject. Thus, a study of pulse-to-pulse variations could provide very informative and complementary results to augment the program for data acquisition under this Signal Corps Contract. This will provide radar data for an effort to discover how and to what extent these variations relate to meteorological processes.

INSTRUMENTATION:

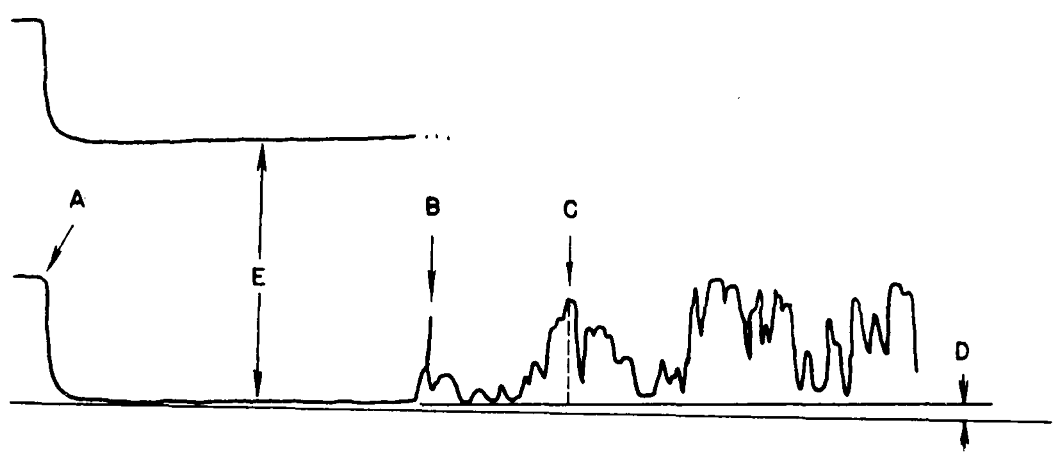
Weather Radar Set AN/CPS-9 provided the basic tool in this study with all other equipment considered accessory or complementary items. A Tektronix Model 545A oscilloscope equipped with a P16 phosphor cathode ray tube and Type K plug-in preamplifier constituted an auxiliary R-scope. A 35mm Fairchild Oscillo-Camera recorded the R-scope trace provided by the Tektronix 545A oscilloscope. Tri-X pan film proved to be the best suited for use in the Oscillo-Camera. This film has high sensitivity without force-development. Suppliers could readily provide bulk 100 foot rolls.

To connect the Tektronix-Oscillo-Camera combination to the Weather Radar Set AN/CPS-9 we proceeded as follows: 1) The Y-axis video input to the oscilloscope came from jack J-1 in the off-center PPI. 2) To synchronize the delayed sweep of the oscilloscope, master trigger pulses from J-202 of the radar go to the "delayed trigger" input jack on the oscilloscope.

Both PPI and RHI radar scope photographs taken immediately after each sequence of SPRAR pictures provide supporting weather radar information. A complete set of radar data requires taking the following steps: 1) Select the sampling volume by adjusting the radar azimuth and elevation angle controls and setting the Tektronix oscilloscope for the desired sweep speed and delay time. 2) While viewing the R-scope display, reduce the receiver gain enough to prevent saturation in the receiver and to prevent system noise from assuming a dominant role in the variations of echo strength studied. 3) Open the oscillo-camera shutter and cause the film to run past the lens at a speed of 38 in/sec. (A sample of such data appears in Figure 2.) 4) At the termination of this film recording, switch the radar to RHI scan

FIGURE NO. 1

FEATURES APPEARING ON A SINGLE PULSE TRACE



A - Transmitting pulse

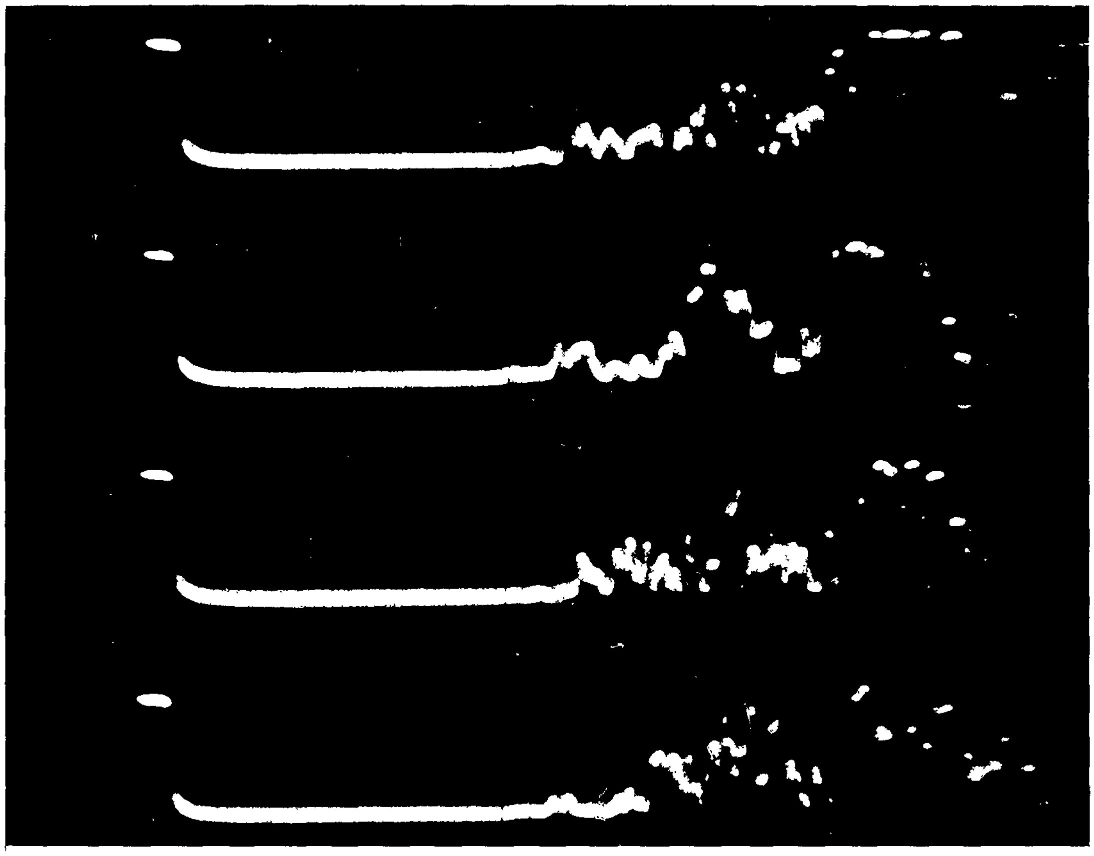
B - 5 mile range mark

C - Dashed line shows amplitude measured for statistical study

D - Angle of trace caused by film movement

E - Trace to trace spacing = 0.0054 sec.

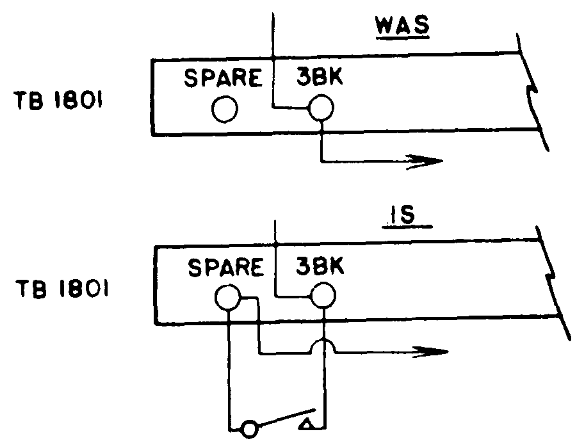
Figure No. 2



Representative SPRAR traces from Fairchild Oscillo-Record Camera on the same azimuth and take several pictures of this display. 5) Switch the radar to azimuth scan at the same elevation angle used when taking the SPRAR data, and take several PPI scope pictures.

Radar echoes from smaller sampling volumes should reveal more pronounced variations because of less tendency toward averaging. Thus, we used the shortest available pulse length. The AN/CPS-9 provides two pulse lengths, 5.0 and 0.5 microseconds, at respective PRF rates of 186/sec and 931/sec. The available rate of film movement has not allowed photographing R-scope traces at the fast rate without overlapping traces on the film. In order to take advantage of the smaller sampling volume a modification to the circuitry of the AN/CPS-9 facilitated using the slow PRF rate with the short pulse. The circuit change appears in Figure 3. At first the radar receiver AFC circuits did not receive enough RF energy at the lower PRF to keep the receiver on frequency. The solution to this problem came with precise tuning of the receiver and with a slight increase in transmitter RF feedback to the AFC circuits.

FIGURE NO. 3



ANALYSIS TECHNIQUE

How long does it take for the radar return signal to achieve independence? Statistical analysis of the variation of instantaneous echo strength can provide insight to this question. As a first effort we examined the length of time required for the correlation coefficient, r, to fall to an arbitrary low value. The correlation coefficient, r, has a value of 1.00 for perfect correlation and zero for perfect independence between the signal strength from one echo and from some succeeding pulse. We used two sampling methods and tested the results for independence at the five percent level of significance.

First Method:

Take data at an arbitrary range or position along the R-scope trace as shown in Figure 1. For the first trace, t_1, measure and record the amplitude of the trace above the base line. Next, measure the amplitude of trace, t_2, at the same range and in the same manner as the first trace. Continue this process for the third, fourth, and so on. Now, compare the measured amplitude recorded for t_1 with that of t_2, t_3 with t_4, etc., considering the traces with the odd numbered subscripts as the reference and the traces with even numbered subscripts as the variable. Now, calculate the correlation coefficient. This permits testing the amplitude of the return signal from a selected sampling for independence over the time interval between two traces.

For longer intervals we follow the same procedure for calculating the correlation coefficient, using the measured amplitudes previously obtained but comparing t_1 with t_3 and t_2 with t_4, etc. Continued calculations for increasing trace intervals eventually should yield calculated values of r low enough to indicate independence.

Second Method:

Whereas the first method used only one point per trace with the comparison made over a large number of trace pairs, this second method makes the comparison between one randomly selected trace pair.

First, a randomly selected single trace provides the reference trace. This trace is then divided up into small increments where one observation, amplitude, will be measured per increment. The desired sample size and optical measurement limitations determine the number of increments. Then compute the correlation coefficient, r, between the selected points on this reference trace and the corresponding points on the succeeding trace.

Both of the above methods give the time-to-independence to the nearest trace interval.

RESULTS:

For 3.2cm radar a conclusion attributed to Fleisher (1) states that "independence between the power from pulse n_o and that from pulse n_i was not reached until the time period between them was of the order of 20 milliseconds". Hitschfeld (2) stated that the time required for decay of the correlation coefficients to one-half their initial value varied from 1.7 to 12 milliseconds for snow. With these facts in mind the 186 traces per second (corresponding to the slow PRF rate of the AN/CPS-9 radar) should show roughly the point where corretation between traces approaches zero, or independence is reached.

We used the first method on two samples, one of 24 pairs and a second of 49 pairs. For the smaller sample we calculated the correlation for first and second, first and third, and first and fourth, pairs as a sequence in time. All calculations, as shown on Table 1, indicate independence. The correlation between adjacent trace pairs for the larger sample led to the same conclusion. To investigate the suggestion that some periodicity or other fluctuation in the trace-pair time sequence might cause an increase in the trace amplitude fluctuation, we then used the second method in an attempt to point up any errors of this type. Four random trace-pairs came from the data which had provided the sample of size 49. Applying the second method with a sample size of eleven, three of these tests indicated independence. The fourth, though showing some correlation, may well provide one of the cases falling into the 5% class which will indicate correlation when chosen as the level of significance in the testing.

Using the 186/sec PRF, or a trace-to-trace interval of 5.38 milliseconds, no correlation appears between traces, indicating independence reached within this period for the data used.

PROPOSED FUTURE RESEARCH:

First calculations of SPRAR correlations indicate that the pulse-to-pulse interval of 5.38 microseconds exceeded the time to independence. A future effort will attempt to obtain usable SPRAR traces at the 931/sec PRF or at some intermediate rate above 186/sec.

Attempts to reveal relationships between meteorological processes and the radar pulse-to-pulse variations might involve many comparisons. These planned comparisons listed below suggest that an entire line of research could possibly develop which would search many other inter-relationships.

1. Comparison between radar long and short pulse operation: This will examine differences between large and small sampling volumes.

2. Comparison between the vertical, crosswind and downwind variations: This will explore any systematic fluctuations caused by air movement as contrasted to those resulting from fine-scale position changes among the precipitation particles.

3. Comparison between different types and phases of precipitation: This could possibly reveal a system for identification of precipitation.

4. Comparison between different areas of a single cumulus cloud: This might yield a scheme for measuring vertical turbulence. (Ref. 2)

5. Comparison between known fixed targets and weather targets: This comparison should determine what magnitude of variations occur in the return signal from a stationary, solid target. This will give the minimum signal variation that could be expected as the result of coherent scatter from a target. Presumably any residual fluctuations in echo signal strength originate in the radar system or the atmosphere between radar set and target.

TABLE NO. 1

Sample No. 1

Sample size - - - - - - - - - - - - - - - - 24

First method

Consecutive trace pairs:
$r = 0.096$

1st & 3rd random trace pairs:
$r = 0.153$

1st & 4th random trace pairs:
$r = 0.248$

1st & 5th random trace pairs:
$r = 0.114$

Sample No. 2

Sample size - - - - - - - - - - - - - - - - 49

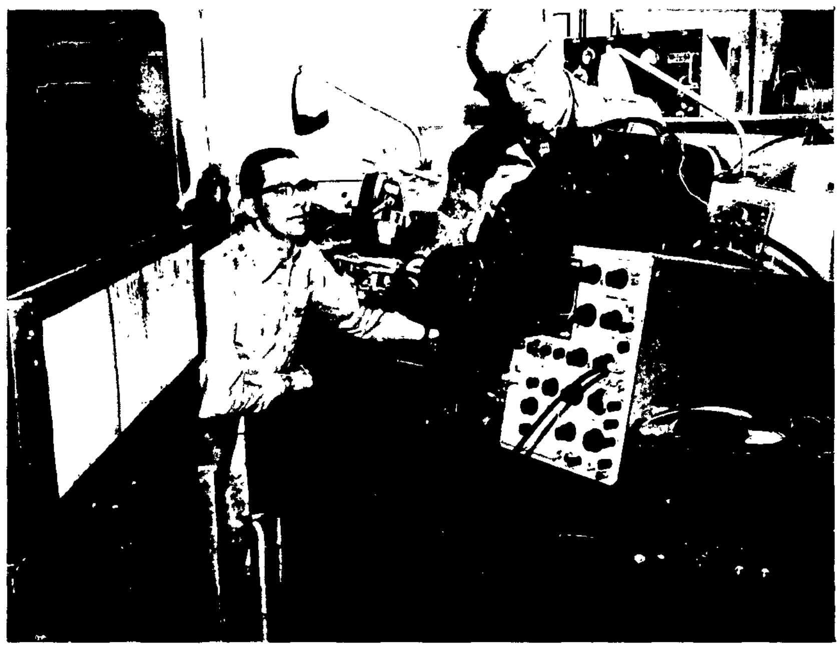
First method

Consecutive trace pairs:
$r = 0.014$

Second method

Film position	r
17 & 17 + 1	0.788
$20-\frac{1}{2}$ & $20+\frac{1}{2}$	0.461
23 & 23 + 1	0.214
29- & 29+	0.279

Figure No. 4



Photograph shows the Fairchild Oscillo-Record Camera and Tektronix model 545A oscilloscope cabled to AN/CPS-9 Radar console.

ACKNOWLEDGEMENT

To Lt. Col. John M. Steigner, USAF, the project group extends grateful thanks for his freely given help and stimulus to complete the work reported here. Col. Steigner's interest, cheerful determination, and sedulous effort made this study possible.

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AN/CPS-9 RHI FILM LOG

Reel	Start	Stop	Date	Remarks
302	1143P	1447P	15 April	Starting with frame 12249 (1253P). Film is for SPRAR back-up.
302	1317P	1415P	19 April	Pictures taken for SPRAR support.
302	0950P	1330P	21 April	Area generally cloudy, but no measurable precip.
302	0430P	1605P	24 April	Front over station at start of run. Hail occurred at station at 1239P from cloud which had been tracked from 0944P.
303	1022P	1545P	27 April	Hail occurred at station at 1335P and snow at 1517P. Showery weather throughout the day. SPRAR support from frames 14968 to 15228.
303	1016P	1623P	28 April	Series of pictures taken at different azimuth for support of PPI pictures taken.
305	1114P	1454P	6 May	Series of pictures taken at different azimuth for support of PPI pictures taken.

AN/CPS-9 PPI FILM LOG

Reel	Start	Stop	Date	Remarks
301	2040P	2230P	25 March	Line precip off coast.
	1155P	1324P	26 March	Light showers around station.
	1537P	1559P	26 March	Light showers around station.
	1220P	1246P	6 April	Tiros support.
	1100P	1520P	8 April	Front east of station, showers west of station.
	1118P	1517P	15 April	Very light showers around station, post frontal.
	1235P	1355P	19 April	Heavy showers to west and east of station.
	0925P	1420P	21 April	Area generally cloudy, but no measurable precip at any of the ground stations nearby.
	0355P	1605P	24 April	Front passage over station at 0400P, at 0850P visual observation showed no precip to west. This series of pictures taken in support of RHI pictures. Hail occurred at station 1239P.
	0950P	1547P	27 April	Front over Cascades, data includes SPRAR #1 from frame 08839.
	0950P	1603P	28 April	Post frontal squall line. Post frontal showers before and after with hail in squall line.

CONCLUSIONS

The initial calculations of correlation between SPRAR traces indicate that signal variations have reached independence within the interval of 0.0054 seconds.

The demonstrated capability to record satisfactorily the data on variation using the SPRAR system now permits a further examination of precipitation echoes in this manner using shorter time intervals, longer pulses, and different synoptic weather systems. This work should proceed in the next quarter.

PROGRAM FOR THE NEXT INTERVAL

1. Task A will continue with effort focused on completion of the literature survey and establishment of operational criteria.

2. Task B will continue with a few observational opportunities before onset of the general summer drought.

3. Task C will bring about a detailed analysis of some of the cases recorded in 1960-61 at McCulloch Peak under the leadership of Mr. L.D. Mendenhall, who will advise with the project group during summer 1962.

4. Dr. Decker will confer with other mesometeorological researchers at their own establishments in Europe and will present a seminar on radar meteorology at the SFIT, Zurich, in early July.

5. Mr. Shreeve will continue the instrumentation of the AN/CPS-9 and will supervise the preparation of the detailed operating doctrine.

IDENTIFICATION OF PERSONNEL

Personnel	Man Hours
1. Fred W. Decker	25
2. Kenneth H. Shreeve	180
3. James W. Sears	25
4. Laura Smothers	320

(Hours of technical and clerical assistants are not included above)

Dr. Fred W. Decker, Associate Professor of Physics and Chairman of the Atmospheric Science Branch at Oregon State University, serves as project director. He has directed previous work in this study and in a predecessor study on Weather Effects on Army Operations, which began in 1954. He received undergraduate and graduate degrees at OSU, the B.S. degree in physics at OSU in 1940, the M.S. degree at NYU in 1943, the Ph.D. at OSU in 1952. He has engaged in research and development in meteorology since 1943. He specializes in physical meteorology and weather radar studies.

Mr. Kenneth H. Shreeve, Research Associate in the Atmospheric Science Branch of OSU, serves as chief radar scientist for this project. He received the B.S. degree at OSU in 1960 and continues to pursue graduate work toward the M.S. degree in meteorology at OSU. In the Army from 1954 through 1957, he had assignments involving electronics instruction and electronic duties in a guided missile battalion. He contributed much enterprise and original creativity to the development of the PREPI system for investigation of reflectivity profiles in horizontal layers such as the bright band.

Mr. James W. Sears, Research Assistant in the Atmospheric Science Branch, serves as data coordinator and radar meteorologist in this project. He received the B.S. degree at OSU in 1960 and continues his work toward the M.S. degree in meteorology at OSU. In the Army on active duty in 1961, he continues as reservist with a local training unit. He has special qualifications in photography and radar mesometeorology upon which he will draw in furthering the work of Task B.

Mrs. Laura Smothers, Research Secretary in the Atmospheric

Science Branch of OSU, serves as office supervisor for this project. She manages the security program and handles the office routine essential to the production of scientific reports and the collating of scientific data required under this study.

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Oregon State University Corvallis, Oregon

INVESTIGATION OF INSTRUMENTATION AND TECHNIQUES FOR ARMY WEATHER OBSERVATION, (Report No. 1)--Fred W. Decker, Kenneth H. Shreeve, James W. Sears

First Quarterly Technical Report 1 May 1962 ____pp (Contract DA-36-039 SC-89186) DA Project 3A99-27-005-07 Unclassified Report.

This report summarizes the preliminary study of the variations in the radar echo intensity from various parts of a precipitation region using the "SPRAR" system. A photographic record of the return from each individual transmitted pulse reveals short-period variations which achieve statistical independence sooner than the transmission of the next pulse, only 0.0054 second later. The report also lists the corresponding PPI and RHI photographs which record the weather conditions in which the tests occurred and other records made for comparison with TIROS observations or for mesometeorological analysis.

1. Weather Observation--Instrumentation and Techniques

2. Contract DA-36-039 SC-89186

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INVESTIGATION OF INSTRUMENTATION AND TECHNIQUES FOR ARMY WEATHER OBSERVATION, (Report No. 17)--Fred W. Decker, Kenneth H. Shreeve, James W. Sears

First Quarterly Technical Report 1 May 1962 ____pp (Contract DA-36-039 SC 89186) DA Project 3A99-27-005-07 Unclassified Report.

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